National Aeronautics and Space Administration

Educational Program	
Educators & Students	Grades 5–8

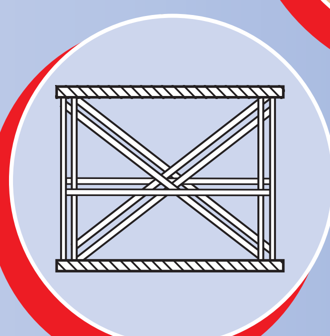
EP-2002-08-401-HQ

NASA Student Involvement Program

Aerospace Technology Engineering Challenge

NASA's mission is

- To understand and protect our home planet,
- To explore the Universe and search for life,
- To inspire the next generation of explorers *as only NASA can.*



Resource Guide

2002–2003 National Competitions

National Aeronautics and
Space Administration

NASA's vision for the future is:

- To improve life here,
- To extend life to there,
- To find life beyond.

NASA's mission is:

- To understand and protect our home planet,
- To explore the Universe and search for life,
- To inspire the next generation of explorers as only NASA can.

You may obtain the official Entry Packet for the 2002–2003 competitions by downloading it from the NSIP website, ***http://education.nasa.gov/nsip***, or you may contact us by e-mail (***info@nsip.net***) or by telephone at 1-800-848-8429.

Welcome to NSIP's newest competition: **Aerospace Technology Engineering Challenge.** This competition invites students to design, build, and test spacecraft structures by using the same process as NASA aerospace engineers. In the process of meeting this challenge, students will strengthen their science inquiry and technological design process skills. It is an opportunity to get involved in real-world engineering questions that are important to the space program.

Use this Resource Guide together with the official NSIP Entry Packet (available on the NSIP website) to submit your entry. The guide is designed for teachers of students in grades 5–8. Feel free to adapt the materials and activities to suit the level appropriate to your students.

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Competition Categories

Grades 5–8	Teams of 2–4 Students

Aerospace Technology Engineering Challenge

NASA aerospace engineers balance the need for speed and power against the need for lighter, stronger materials. The process of technological design presents engineers with the challenge of balancing the strengths and weaknesses of the materials needed to build a spacecraft. They must also balance those factors against other kinds of constraints such as the overall weight, size, and production costs.

Design and Build an Aerospace Structure!

The Aerospace Technology Engineering Challenge is an opportunity for students to face some of the same challenges that NASA engineers and scientists deal with every day. Student teams design and build a structure and make it as light as possible, yet strong enough to withstand the load of three successful launches. This structure, called the "thrust structure," is an essential part of aerospace engineering: it is the part that attaches the engine to the spacecraft.

The figure below shows the thrust structure of the Titan spacecraft. The thrust structure protects the rest of the spacecraft from the enormous force that the engine exerts in order to lift hundreds of tons from Earth to orbit.

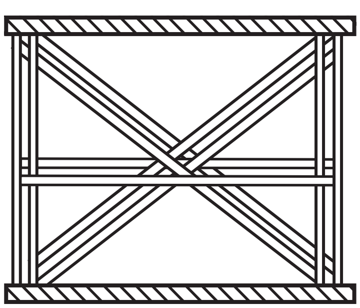
Spacecraft structures, like Titan's thrust structure, are made of special materials and come in a variety of shapes and sizes. The structure students will design and build is about the size of a small paper cup, and made from sticks, cardboard, and hot melted glue (see diagram to the left of the Titan). Despite these differences, the job of the thrust structure is the same no matter what it is made of or how big it is. Furthermore, the engineering process of designing, testing, and improving the structure is the same for students as it is for scientists and aerospace engineers.

What Is the Challenge?

Student teams place their structure between a 1-kg test "rocket" (a 1-liter plastic bottle filled with water) and a launch lever that will send the rocket about 1 meter high. If the structure passes the first test it will be tested again to see whether it can withstand three launches. Teams will use what they learn from each test to improve the design until they arrive at their lightest and strongest structure.

How to Get Started

This Resource Guide explains the basics of the Challenge, how to put a competition entry together, and how the entries will be judged. The detailed instructions for the design, creation, and testing of a thrust structure are contained in NASA's *Spacecraft Structures* guide.



Titan main engine and thrust structure.

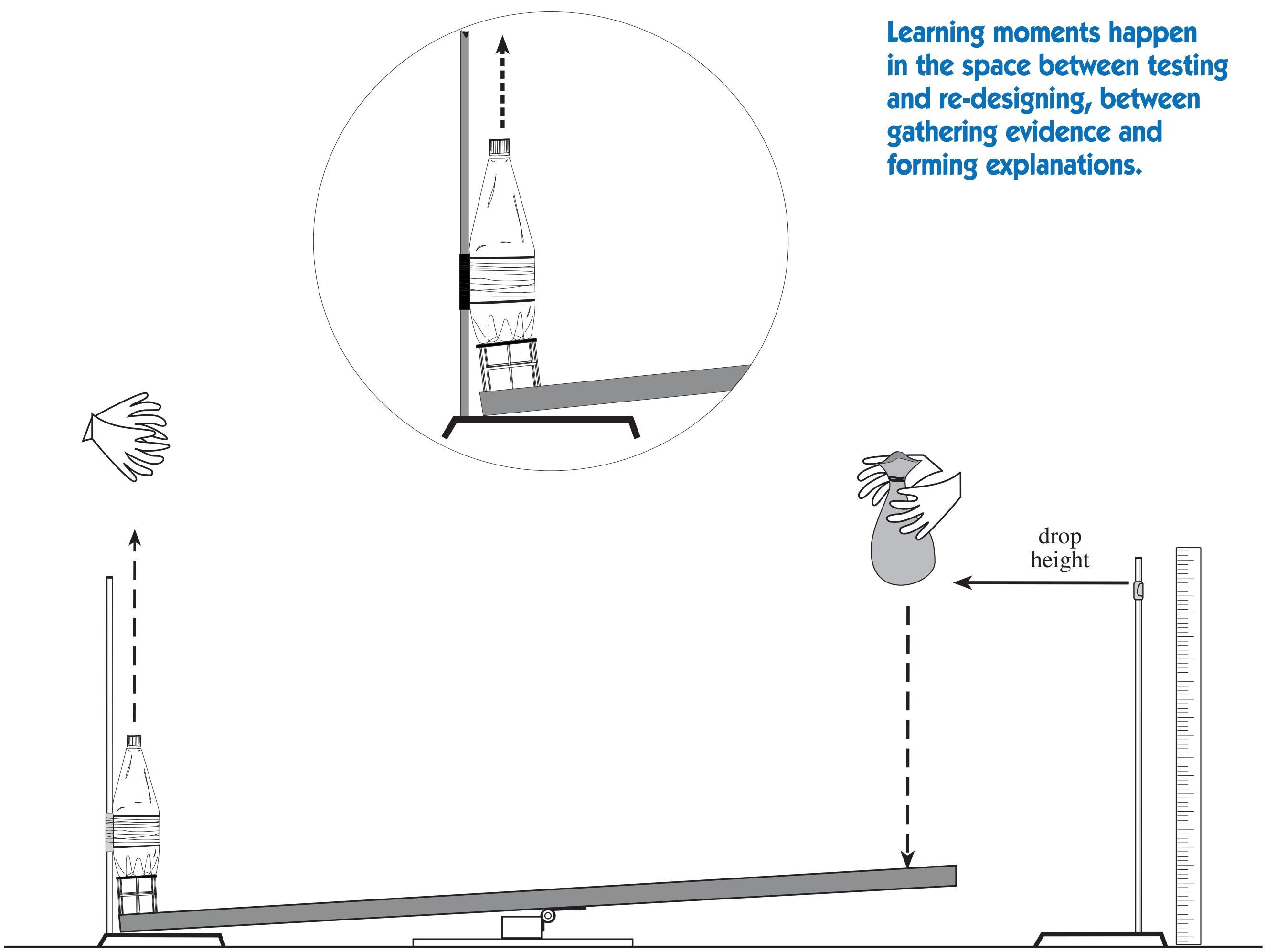
The materials list and one activity from that Guide have been reproduced here for your reference (see the materials list and sample activity on pages 12–16 below). The full *Spacecraft Structures* guide is an extensive step-by-step guide and includes detailed activities, drawings, design tips, worksheets, photocopy masters, and a variety of other resources to bring this great opportunity into your classroom. Teachers may decide to use part or all of the *Spacecraft Structures* guide and modify its resources to best fit the needs of their students' grade level and capabilities. To download the full *Spacecraft Structures* guide from the Earth-to-Orbit (ETO) web site go to http://eto.nasa.gov and click *"The Challenges"* and then click on *"Spacecraft Structures Design Challenge."* Visit the ETO website to find other supporting materials.

The Earth-to-Orbit program features other Engineering Design Challenges in the Aerospace Engineering area. Each Challenge comes with extensive support materials, including a guide. The ETO program was conceived and developed at two NASA centers that focus on aerospace technology: Marshall Space Flight Center in Huntsville, Alabama, and Dryden Research Center in Edwards, CA. Visit these sites for great NASA resources in aerospace technology and science:

NASA Marshall:
http://www.msfc.nasa.gov

NASA Dryden:
http://www.dfrc.nasa.gov

Learning moments happen in the space between testing and re-designing, between gathering evidence and forming explanations.



Preparing Your NSIP Entry

Entry components fall into two main groups: Evidence and Explanation.

A. Evidence: Successful engineering depends on sharp observations, clear descriptions, complete records, and clear drawings. These are the building blocks of the engineering process.

B. Explanation: Thinking skills, problem solving, and creativity grow stronger when students explain what they've learned to an audience of their peers. Explanation is the mortar holding it all together.

1. NSIP Forms

Follow the instructions in the NSIP Entry Packet, which includes competition rules and entry forms. The Entry Packet is available at http://www.nsip.net/entry

2. Project Summary

Describe how many designs were tested, how many survived, and summarize student conclusions about designing a strong, lightweight thrust structure. Maximum: 50 words. This summary should be the same as the one that goes on the NSIP Entry Form.

3. Evidence & Data

NSIP provides teams with a log and two worksheets to record their investigation activities. The log helps them keep track of what was done by whom, etc., while the design and test worksheets enable students to keep records of the team's detailed design specifications and test results. Students are to select only three design sheets and three test result sheets for inclusion in their NSIP entry. Students must make their selections carefully; the particular cases they choose should tell the story of how the team improved their initial designs by learning from both successful and failed launches. Their selection should include sheets for: a) their best structure, b) one of their first structures, and c) a failed structure from which they learned important lessons. A quick perusal of the Judging Rubric (see pages 17–18, below) reveals that of 100 possible points, 60 are devoted to presenting evidence of their investigations.

3a. Thrust Structure Development Log (Worksheet A)

Teams are to record an overview of their investigation activities, including their discussions with mentors and other teams. The purpose of this Log is to keep track of all efforts, from start to finish. By prompting them for key pieces of information, the Log will help students demonstrate their level of effort and diligence in meeting the engineering challenge. The Log will provide NSIP judges with a brief summary of the team's process of technological design development.

3b. Design Specification Worksheets (Worksheet B)

The Design Specification sheet details the information that students must record before each test. These worksheets are provided by NSIP to help students document the design process for each structure they build. Because they are asked to include Design sheets for only three cases it is crucial that students choose these carefully. Their selection should include sheets for: a) their best structure, b) one of their first structures, and c) a failed structure from which they learned important lessons. Remind the students that a structure may fail, but the test was a success. Failures are important since many of the most useful engineering lessons are about what went wrong.

3c. Test Results Sheets Worksheets (Worksheet C)

The Test Results sheet prompts the team to record important information before and after each test. The worksheet provides space for original student sketches, description of test results, and identification of controls and variables for possible modification. Because they are asked to include Test Results sheets for only three cases it is crucial that students choose these carefully. Their selection should include sheets for: a) their best structure, b) one of their first structures, and c) a failed structure from which they learned important lessons. In addition, teams will also enter data from their test results into a table that shows the weight and the number of launches that each design survived. This Table of Test Results will provide judges with an instant look at the two key facets of good thrust structure design: weight and strength.

Preparing Your NSIP Entry

Entry components fall into two main groups: Evidence and Explanation.

A. Evidence: Successful engineering depends on sharp observations, clear descriptions, complete records, and clear drawings. These are the building blocks of the engineering process.

B. Explanation: Thinking skills, problem solving, and creativity grow stronger when students explain what they've learned to an audience of their peers. Explanation is the mortar holding it all together.

4. Narrative: The Design Development Process

The worksheets help students record data and information which they will analyze to improve their structures. If these sheets are carefully, legibly, and thoroughly filled during the design and test phases they will contain much of what is required to prepare this section of the Entry. The Narrative has two basic parts: a) *Description* of what and how the Challenge was met, and b) *Explanation* of what concepts were learned and applied. These are explained in further detail below:

4a. Thrust Structure Development

In this section, ***describe*** the steps students took to make their favorite design strong and light. The purpose is to recount the sequence of events; telling the story in order from beginning to end, and should refer to specific test results and other student records where appropriate. The *Spacecraft Structures* guide provides many tips on the design process, for example, look at pages 39–42. Some ways the team might improve their designs, include: changing variables one at a time, examining other structures, learning from other teams, consulting an engineer, doing research on structures and forces, and just trying something different at the right moment! This section should not exceed 500 words.

4b. Discovery and Application of Concepts

What concepts did students learn and apply in the process of improving their thrust structure? For this section of the report students should crystallize all the lessons they learned, for example, about forces, symmetry, and the materials utilized, etc. The purpose of this section is to ***explain*** what they learned and to present their conclusions. *The learning moments occur in the space between tests and redesigns.* The Design Specification and Test Results sheets prompt students to capture these learning moments and provide the evidence for the conclusions that are explained here. The *Spacecraft Structures* guide discusses how to use these sheets to maximum advantage. Students may use up to 700 words to explain what they learned about making structures that are light and yet strong.

5. Background Information

The final section of the NSIP Entry is brief (no word limit) and provides basic information.

5a. Materials

Describe the materials used to build the structure, especially the craft sticks. Attach two of the craft sticks to the Background section of each copy of the Entry (NSIP requires three copies of each entry).

5b. The Launcher

Describe your launcher, (see the *Spacecraft Structures* guide, pages 16–18) including,

i. the overall length of the launch lever,

ii. the length of each of its two arms,

iii. the range of vertical motion of the launch lever,

iv. the weight and construction of the drop weight,

v. the height from which the weight was dropped.

5c. Experimental Conditions

It is acceptable to modify the materials, the launcher, or other experimental conditions stated in the *Spacecraft Structures* guide. Briefly describe all modifications that the team or teacher introduced to the basic system.

5d. Resource Credits

What information or other kinds of assistance did students find to be helpful? Cite all references (books, guides, websites, etc.), including the people who acted as advisors. It's smart to learn from others and important to acknowledge them.

Worksheet A

Thrust Structure Development Log

Team: ______________________

Date/Time	Place	Struc-ture #	Observations/Comments	Mentor(s) Consulted	Recorder's Initials	Observer's Initials
10/10/01 10:00 am	Science Lab	1a	We decided on a triangle design, like the kind used in some bridges. Team built design. Will test later today.	JM	MJQ	MJQ, JL, DT, JRW
10/10/01 11:00 am	Science Lab	1a	Two sticks broke during second launch, cardboard crumpled. Rocket rose to 80 cm. Advisor recommend we use more struts, or else use same design but brace the struts with something.	JM	JKL	MJQ, JL, DT, JRW

Worksheet B

Design Specifications Sheet

Date: ________ Class: ____________

Design Number

Thrust Structure Weight (in grams)

Team: ________________________________ **Designers' Initials:** ____________________ **Advisors' Initials:** ____________________

Sketch your design, showing materials used, glue points and dimensions (in cm).

Reflections on Design:

a) *Explain why* you think this design will be successful.
b) *Describe how* resources (advisors, science/engineering/historical references, etc.) were used to develop or select this design.
c) If this design is a modification of a design previously tested: identify which features you are keeping ("controls") and which you are changing ("variables").
d) *Explain why* you think the change(s) you have made will improve the design.

Worksheet C

Test Results Sheet

Date: ________ Class: ______________

Design Number

Thrust Structure Weight (in grams)

Team: ____________________ **Designers' Initials:** ______________ **Advisors' Initials:** ______________

Sketch your model after testing. Show failure points, if any.

Test #	Damage (yes/no)	Rocket Altitude	Drop Height	Comments
1				
2				
3				

Observations and Reflections:

a) which features seemed effective and which did not?

b) If this is a modification of a previously tested design describe what was modified and whether this improved the design.

c) Identify design features that you might change next time.

Sample Pages from NASA's Spacecraft Structures Guide

The following pages are included to give teachers a sample of the excellent resources of the *Spacecraft Structures* guide: a comprehensive and detailed list of materials is followed by an activity that introduces students to the process of testing their thrust structures. The activity is not meant to stand alone: it depends on other sections of the *Spacecraft Structures* guide (for example, instructions for building the launcher, and helpful guidelines for classroom use.) The *Spacecraft Structures* guide is essential to preparing a successful entry to NSIP.

Download the full *Spacecraft Structures* guide at **http://eto.nasa.gov** and click *"The Challenges"* and then click on *"Spacecraft Structures Design Challenge."* If you have problems downloading, viewing, or printing the guide, or have any questions about preparing your entry, write to **help@nsip.net**, or call the NSIP toll-free number (800-848-8429).

Teacher Preparation

In order to prepare yourself and your classroom for this engineering design challenge, you should:

- Use the Background Information section of this guide, as well as the Earth-to-Orbit Engineering Design Challenge web site to familiarize yourself with spacecraft structures used by NASA and the science and engineering concepts you will be introducing.
- Read through the day-by-day activities in the following section of this guide
- Gather the required materials
- Build the launcher
- Build the test rockets
- Practice the test procedure with your own designs
- Prepare the materials for the classroom
- Set up the classroom
- Organize students in teams
- Review safety procedures
- Notify parents using the flier included in the Masters section

Required Materials

	Approximate cost per unit	**Minimum quantity for a few teams (60 structures)**	**Recommended quantity for 12–15 teams (120 structures)**	**Add for each additional team (10 structures)**
Craft Sticks	1/2¢	1500	3000	250
Dowels	15¢ to 50¢ for 3 ft	5	5	0
Hot-Melt Glue (low-temperature type)	5¢ to 50¢ per stick	12	20	2
Corrugated Cardboard	free	60	120	10
35 mm Film Cans	free	10	20	1
1-liter Soda Bottles	free or 5¢	8	20	1
2-liter Soda Bottles	free or 5¢	3	5	0
Weight	$2.35 for a 50-lb bag of sand	20 to 50 lbs total		
Brass Launch Tubes	80¢ for 4 inches	4	8	1
Package Tape	$2.00	1 roll	1 roll	0
Small Paper Cups 4-oz, waxed	2¢ or 3¢	12	36	3

Excerpt from *Spacecraft Structures* Guide (see http://eto.nasa.gov/challenge.html to obtain a complete guide).

Session 2

Design 1

In this session, students design and build their first thrust structure using the provided materials. It is important during this session to establish consistent procedures for testing including:

- Pre-test approval of design and recording sheet
- Oral presentation of key design features by students before launch
- Accurate testing and reporting of results on Test Results Sheet
- Post-test discussion of the design and the test results

Learning goals

- Practice construction techniques including use of glue-pot or glue gun
- Recognize the need for clear documentation
- Practice documenting design
- Practice making and recording observations
- Begin thinking about how to make designs strong and lightweight

Materials

- Launch stand, sand bag, ring stand
- Craft sticks
- Glue guns and glue sticks
- 3-1/2 inch square pieces of cardboard
- Paper cups (optional)
- Transparency and handouts of recording sheets
- Chart paper (or chalkboard) for recording launch results
- A balance or scale accurate to a tenth of a gram
- Overhead projector (optional)

1. Review the design challenge and the design constraints

Make sure students understand the challenge. Use the master to review it.

2. Introduce the materials

Explain to students that they must build a thrust structure using the craft sticks and hot-melt glue. The structure should be attached at the top to a square of cardboard on which the bottle will sit. The structure is <u>not</u> attached to cardboard at the bottom.

3. Review safety issues

Point out to students that the tip of the glue gun and the metal strip at the front of the glue pot are hot and should be avoided. Review the procedure for burns. Remind students to wear safety goggles when launching their model.

Excerpt from *Spacecraft Structures* Guide (see http://eto.nasa.gov/challenge.html to obtain a complete guide).

4. Introduce the recording sheets

Introduce the Design Specifications and Test Results sheets. One way is to make a transparency of each sheet and project it on the overhead. Tell students that these are where they will record all the details of their designs and the results of their testing. Explain that engineers need to keep careful records. Ask students why record keeping is so important. Discuss each part of the "Design Spec" and "Test Results" sheets. Make sure students understand that one sheet shows their model *before* testing and that the other shows it *after* testing.

Remind students to keep track of their designs by numbering their recording sheets. Remind them that they will use their recording sheets to construct a storyboard at the end of the challenge.

Explain to students the importance of a detailed sketch of their design. Their goal in sketching should be that someone looking only at the sketch could reconstruct their design. You may wish to show a completed recording sheet as a sample.

Two sketching techniques to introduce are *detail views* and *section* or *cut-through views.* A detail view is a separate close-up drawing of a particular portion of the design that may be difficult to show clearly in the drawing of the full design. A section view shows what the design would look like if it were sliced in half. It enables the artist to show hidden parts of the design.

As an extension activity, have students try to reconstruct another team's design using only the recording sheet. Assess the recording group on the quality of the sketch and the constructing group on their ability to interpret the sketch.

In addition to answering the questions on the design spec sheets, students should also keep running notes, diagrams, questions, research findings, data, etc. in a journal or log. These journals could be as simple as notes taken on the back of the design spec sheet. A journal will provide an excellent resource for documenting the experience when a student needs to make the storyboard.

5. Explain the test procedure

- When their design is completed, the team completes a recording sheet and brings the model and the recording sheet to the teacher.
- The teacher checks the recording sheet for completeness and accuracy.
- The teacher checks that the model has conformed to all design constraints.
- Before their model is tested, each team must do a brief oral presentation for the entire class in which they describe the key features of the design.
- During the testing, the team should carefully observe and record the performance of their design.

6. Students design and build their models

If you did not have time to complete the demonstration of a poorly designed model, do it now. See step 7 in Session 1.

Allow 10–15 minutes for this first design and build. Establish a cut-off time when you will begin testing. Teams that do not have designs ready to test by the cut-off time must wait until the next round of testing.

Excerpt from *Spacecraft Structures* Guide (see http://eto.nasa.gov/challenge.html to obtain a complete guide).

7. Approving models for testing

When a team delivers their design and recording sheet for testing, check the following:

- ❑ Model uses only allowable materials
- ❑ Model is at least 5 cm tall
- ❑ A 35mm film canister (without lid) fits entirely inside the thrust structure
- ❑ The model has a team name or identifying mark on it
- ❑ The recording sheet is completely filled out, including a satisfactory sketch

If the model is approved, place it on the testing station table. You might call this "being on deck."

8. Test the models

Begin testing when most of the teams' designs have been approved. Have students stop working and gather around the launch station.

Older students may be able to continue working while other teams have their models tested. For this arrangement to work, you will need to locate the launch station in a central location where students can view it from their work areas.

As an option, you may wish to classify the models once each team has presented. Students may come up with classifications based on design strategies.

Before launching, have a member of each team stand and hold up the model or show it around to all other students. The representative should explain:

- Key features of the design
- Why those features were used
- Where the idea came from (a previous design, another team's design, another type of structure, etc.)

Assign a student to record the results of each test on a chart on the chalkboard or a large sheet of paper. The chart should include the following columns:

Team	Design #	Launch to Orbit (Y/N)?		
		1	2	3

You may also want to include a column for "design strategy" if you choose to classify the designs.

Test each team's model three times in succession with no repairs allowed between launches. If you have more time, you may wish to increase the number of launches per model. Inspect the model after each launch. Students should make notes about which structural members failed or are in danger of failing.

Excerpt from *Spacecraft Structures* Guide (see http://eto.nasa.gov/challenge.html to obtain a complete guide).

A failed launch occurs when the rocket does not make it into orbit. A failed launch also occurs when the design no longer meets the design constraints, that is, it is less than 5 cm high or a film canister no longer fits inside. (Important: do not leave the film canister in the model when launching.)

9. Discuss the results of testing

The post test discussion is critical to expanding students' learning beyond the design and construction techniques and connecting their design work with the science concepts underlying their work.

Encourage students to hold the model and use it to illustrate their point when they talk about a particular design feature.

Now is a good time to review the section "Linking design strategies and observations to science concepts."

If one side of the structure has collapsed, help students think about the importance of balanced loads.

For each model, you should pose the same guiding question:

> "How did this structure transmit the force of launch from the lever to the bottle?"

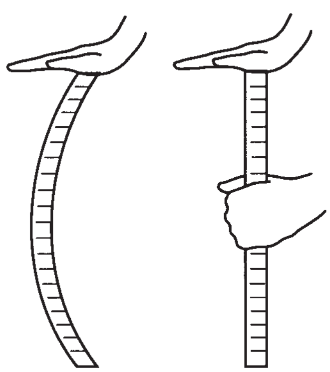
Other discussion questions might include:

- What happened to each part of the thrust structure during the testing?
- Did any parts of the design seem to fail before the rest? Why?
- Which design features were most effective? What made the designs effective?

Have students trace the path of the force through the structural members. See further discussion of how to do this in the section "Linking design strategies and observations to science concepts."

Record (or have a student record) the most successful design features on a transparency or on a wall chart. This list should be expanded and revised throughout the activity as the students collectively discover which designs are strong and lightweight.

If any of the columns in the structure have buckled, help students think about how to strengthen the posts, for example, through bracing. Here is an interesting demonstration of buckling: Take a flexible ruler or meter stick. Stand it up on the floor or table. Press straight down on the top end until the ruler begins to bow out or buckle.



Bracing a ruler to prevent buckling.

Try the same experiment with rulers of different lengths but of the same thickness. Show that any post or column buckles if placed under a sufficient load. But notice that the shorter rulers can support more load without buckling. Then ask a student to grasp and hold steady the middle of the ruler. Repeat the pressure on top with your hand. Show that because the ruler is braced in the middle it is effectively two short columns rather than one long one.

You could also demonstrate the relationship between buckling and the length of a column by using a toilet paper tube and a paper towel tube. Load both with books. The longer one will buckle first. (Make sure they are the same diameter and made of the same thickness of cardboard.)

Excerpt from *Spacecraft Structures* Guide (see http://eto.nasa.gov/challenge.html to obtain a complete guide).

Aerospace Technology Engineering Challenge
Judging Rubric

Grades 5–8

This rubric is designed for all grade levels. Teachers should adapt the rubric to match their students' ability levels.

Entries must meet the following minimum standards. Entries not in compliance will not be judged.

- Entries must include all three worksheets (A, B, and C) and the student report.

A. EVIDENCE AND DATA 60 Points Maximum

LEVEL	1. DEVELOPMENT LOG (Worksheet A)	2. DESIGN SPECIFICATIONS (Worksheet B)	3. TEST RESULTS (Worksheet C)
0	No detailed record of the design, building and testing. Little evidence of team work.	One worksheet. Poor quality of work. Little/ no original student drawings, measurements are present. Controls and variable(s) not identified.	One worksheet. Poor quality of work. lacks original student drawings, description of test results data, or explanation for modification of controls and variable(s).
1	Incomplete record of the design, building and testing. Some evidence of team work.	One worksheet. Some original student drawings, precise measurements, or data are present. Controls and variable(s) not identified.	One worksheet. Some original student drawings, description of test results, and identification of controls and variable(s).
2	Acceptable record of the design, building and testing. Sought advice from teacher. Some evidence of team work.	One to two worksheets with original student drawings, precise measurements, and thoughtful ideas. Some explanation for modification of controls and variable(s).	One to two worksheets with original student sketch of model, description of test results, and identification of controls and variable(s).
3	Comprehensive record of the design, building and testing. Sought advice from teacher, engineers, or other resource people. Evidence of team work is obvious.	Three worksheets with original student drawings, precise measurements, and thoughtful ideas. Some explanation for modification of controls and variable(s).	Three worksheets with original student sketches, description of test results data, and identification of controls and variable(s) for possible modification.
4	Exemplary record of the design, building and testing. Sought advice from engineers, teachers, or other resource people. Evidence of team work is obvious.	Three exemplary worksheets with original student drawings, precise measurements, and thoughtful ideas. Clear explanation for modification of controls and variable(s).	Three exemplary worksheets with original student sketch of model, description of test results data, and identification of controls and variable(s) for possible modification.
	Level _____ × 5 = _____ points	Level _____ × 5 = _____ points	Level _____ × 5 = _____ points

Subtotal points from this page __________

B. NARRATIVE OF DESIGN DEVELOPMENT 40 Points Maximum

LEVEL	**4. NARRATIVE** *(Thrust Structure Development; Background Info.)* ***Is the process of developing the thrust structure described in detail?***	**5. REFLECTION** *(Discovery and Application of Concepts)* ***Are there clear explanations of what was learned?***	**6. COLLABORATION** *(Teamwork & Resources)* ***Is there collaboration with experts and others? Are other research resources credited?***	**7. APPLICATION** *(Discovery and Application of Concepts)* ***Are the trade-offs involved in technological design discussed ?***
0	No detailed description of process used to develop the best designed structure; no attention to failed designs.	Did not identify design questions, problems and/or possible solutions. No science concepts explored.	No resource credits (people, historical, science/ engineering references, other activities) that support their process of design.	No discussion of the trade-offs involved in technological design, such as properties of materials (rigidity, elasticity, etc), and the weight of structures made out of them.
1	Some description of process used to develop the best designed structure; little attention to failed designs. No review of data or ongoing questions.	Few design questions, problems, or possible solutions relating to successful and/or failed launches. No review of data or ongoing questions. No science concepts explored.	Incomplete statement of student discussions and resource credits (people, historical, science/ engineering references, other activities) that support their process of design.	Some understanding of the trade-offs involved in technological design, such as properties of materials (rigidity, elasticity, etc) and the weight of structures made out of them.
2	Acceptable description of the process used to develop the best designed structure; some discussion of failed designs. Some review of data or ongoing questions.	Some design questions, problems and/or possible solutions relating to successful and/or failed launches. Some review of data or ongoing questions. At least one science concept explored.	Acceptable statement of student discussions and resource credits (people, historical, science/ engineering references, other activities) that support their process of design.	Acceptable understanding of the trade-offs involved in technological design, such as properties of materials (rigidity, elasticity, etc) and the weight of structures made out of them.
3	Comprehensive description of the process used to develop the best designed structure; discusses lessons learned from failed design. Good review of data and questions.	Comprehensive report of design questions, problems, and possible solution relating to successful and failed launches. Good review of data and questions. At least one science concept explored	Comprehensive statement of student discussions and related resource credits (people, historical, science/ engineering references, other activities) that support their process of design.	Comprehensive understanding of the trade-offs involved in technological design, such as properties of materials (rigidity, elasticity, etc) and the weight of structures made out of them.
4	Exemplary, detailed descriptions of the process used to determine the best designed structure by identifying appropriate problems during technological design. Detailed review of data and questions.	Exemplary report identifying design questions, problems and creative, thoughtful solutions relating to successful and failed launches. Detailed review of data and ongoing questions. 1-2 science concepts explored	Exemplary statement of student discussions and related resource credits (people, historical, science/ engineering references, other activities) that support their process of design.	Exemplary evidence of an understanding of the trade-offs. Discussion includes strength vs weight trade-offs among other constraints of technological design.
	Level _____ × 2.5 = ______ points	Level _____ × 2.5 = ______ points	Level _____ × 2.5 = ______ points	Level _____ × 2.5 = ______ points

Subtotal points from this page __________

Total points __________

Resources

These resources are updated periodically. Check the Aerospace Technology Engineering Challenge web site at ***http://www.nsip.net/competitions/atec/index.cfm*** for the best and most up-to-date version.

About the Space Shuttle

http://www.nasa.gov/qanda/space_shuttle.html

NASA Facts On Line: ***http://www-pao.ksc.nasa.gov/kscpao***

About the Space Shuttle Structure

Introduction to the Space Shuttle: Shuttle Systems

http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/sts_coord.html

About Space Vehicles

International Reference Guide to Space Launch Systems. Steven J. Isakowitz. AIAA Press, Washington, D.C., 1995.

The History of Developing the National Space Transportation System. Second Edition. Dennis R. Jenkins. D.R. Jenkins, Harbor Beach, Fla., 1996.

Halfway to Anywhere: Achieving America's Destiny in Space. New York: M. Evans and Co. 1996.

Stine, G. Harry. *Handbook of Model Rocketry.* New York: Prentice-Hall Press. 1987.

About New Space Vehicles

"A Simpler Ride Into Space" by T.K. Mattingly. *Scientific American,* October 1997, pp. 121–125.

"The Way to Go in Space" by Tim Beardsley. *Scientific American,* February 1999, pp. 80–97.

About Engineering and Careers

www.discoverengineering.org
A new web site, Discover Engineering Online, lets adolescents investigate a host of engineering achievements. Aimed at inspiring interest in engineering among America's youth, the site is a vast resource. Among the many features of the site is information on what engineers do and how to become one. Designed specifically for students in grades six through nine, the site has links to games, downloadables, and powerful graphics, as well as to web sites of corporations, engineering societies, and other resources. One section, for example, lists several "cool" things tied to engineering, such as the mechanics of getting music from a compact disc to the ears of a teen, how to make a batch of plastic at home, or learning how to fold the world's greatest paper airplane.

http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Careers/

NASA Web Sites

http://spacelink.nasa.gov/
SpaceLink: An Aeronautics and Space Resource for Educators

http://core.nasa.gov/
The worldwide distribution center for NASA-produced multimedia materials

http://education.nasa.gov/
A link to the many education resources provided by NASA

http://www.dfrc.nasa.gov/
Dryden Flight Research Center: has a photo gallery of more than 1,000 digital images of research aircraft

http://www1.msfc.nasa.gov/
Marshall Space Flight Center: contains many science, technology, and education resources in aeronautics, space and Earth science, and microgravity.

Additional Reading

P primary	***I*** middle school
E elementary	***A*** advanced 9-12+

Girls Think of Everything: Stories of Ingenious Inventions by Women. Catherine Thimmesh. Illustrated by Melissa Sweet. Houghton Mifflin. 64 pp. Trade ISBN 0-395-93744-2. (I) Women have changed our lives with their inventions from windshield wipers to bulletproof vests. Thimmesh show us their inspirations and path to innovation. We learn how the inventors overcame obstacles and used creative thinking to solve problems. Resources, Index, List of Women Inventors.

The Technology Book for Girls and Other Advanced Beings. Trudee Romanek. Illustrated by Pat Cupples. Kids Can Press. Trade ISBN 1-55074-936-6; Paperback ISBN 1-55074-619-7. (E, I) Focusing on the fun aspects, this book shows how relevant technology is in the world and tries to entice girls to explore career fields. In-depth explanations with suggested activities complement science fair project ideas. A good choice to show girls how exciting the world of science and technology can really be. Bibliography, Index.

Brooklyn Bridge. Lynn Curlee. Illustrated by the author. Athenaeum Books for Young Readers. 40 pp. Trade ISBN 0-689-83183-8. (E, I) This engaging book describes the engineering challenges that had to be surmounted to build the Brooklyn Bridge and tells of the enormous efforts of the workmen. The charming illustrations reflect the period during which the bridge was built and include excellent diagrams outlining important structural features of the building process. Table of Bridge Specifications, Timeline, Bibliography.

Building Big. Written and illustrated by David Macaulay. Walter Lorraine Books/Houghton Mifflin. 192 pp. Trade ISBN 0-395-96331-1. (A) This companion to the PBS series "Building Big" provides insight into the forces architects take into account as they design structures and the techniques used to overcome the challenges of building big. Although this book does not use metric measurement, clear, well-labeled illustrations show the reader details of the structures explained in the text. Glossary.

How Tall, How Short, How Faraway. David A. Adler. Illustrated by Nancy Tobin. Holiday House. 32 pp. Trade ISBN 0-8234-1375-6. (P) In this wonderful hands-on concept book, easy technological measuring tools are superbly introduced and explained. Practical explorations are provided for young students to achieve a deeper understanding of measurements and measuring. The informative text and colorful illustrations clearly explain the difference between customary and metric systems.